CEDIM
Center for Disaster Management and Risk Reduction Technology
KIT Karlsruhe Institute of Technology
GFZ Helmholtz Centre Potsdam
CATDAT risklayer Integrated Historical Global Catastrophe Database
SOS
EMI Earthquakes and Megacities Initiative
SAI | SOUTH ASIA INSTITUTE Heidelberg University

CEDIM Forensic Disaster Analysis Group, CATDAT and Earthquake-Report.com

Nepal Earthquakes – Report #3

12.05.2015 – Situation Report No. 3 – 16:00 GMT

Report 3 Contributors:

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Official Disaster Name	Date	UTC	Local	CATDAT_ID
Nepal EQ	**25-Apr-2015**	**06:11:26**	**+5.45**	**2015-128**

Preferred Hazard Information:

EQ_Latitude	EQ_Longitude	Magnitude	Hyp. Depth(km)	Fault Mech.	Source	Spectra
28.18	**84.72**	**7.76Mw**	**18 (25.04.2015)**	**Thrust**	**GEOFON**	**Avail.**
27.78	**86.12**	**7.2Mw**	**15 (12.05.2015)**	**Thrust**	**GEOFON**	**Avail**
		Duration: 80s				

Location Information:

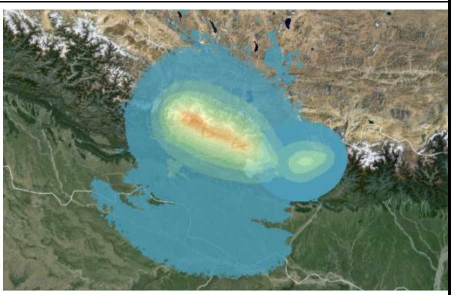
Country	ISO	Dev. Region	Most Impact	Building PF	HDI (2015)	GDP nom. USD	Pop. (2015)
Nepal	**NP**	**Western**	**Gorkha**	**Average**	**0.542**	**3.48 bill.**	**5.27 mill.**
Nepal	**NP**	**Central**	**Kathmandu**	**Average**	**0.558**	**8.84 bill.**	**10.35 mill.**

Preferred Hazard Information:

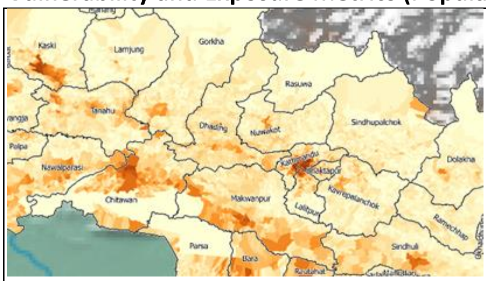
MSK-64	MMI	PGA	**Key Hazard Metrics**
VIII-IX	VIII-IX	0.5-0.7g	Gorkha (VIII-IX), Sindhupalchok (VIII), Dolakha (VIII) Kathmandu (VII-VIII, 0.16g), Patna (IV-V), New Delhi (II-III)

Hazard Description (Intensities and Ground Motion)

Intensities reached VIII on the MMI scale – very well built structures received slight damage. Older buildings suffered great damage. There was also limited liquefaction and many landslides. The epicentral damage seen corresponds to VIII and perhaps very isolated VIII-IX locations on the MMI scale. Over 50 aftershocks > Mw4.7 have occurred, with magnitude 5 and 6 earthquakes continuing to pepper the region east of the epicenter. The fault sense can be seen easily from USGS, Chinese and Geofon data, with the fault break running parallel to the Himalayas toward Kathmandu. At least 60 aftershocks have been strong enough to be felt. A triggered earthquake occurred on the 12th May 2015.



Vulnerability and Exposure Metrics (Population, Infrastructure, Economic)



Population distribution across Nepal per ward.

Nepal has a net capital stock around $39 billion USD with approximately 28.8 million inhabitants. In terms of capital and GDP it is an extremely poor nation with less than $700 (USD) GDP per capita in 2015. It is mountainous in nature and has the chance for many landslides. Kathmandu and the Central and Western regions are key tourist areas for Nepal among others with the area accounting for 5% of GDP through tourism (direct/ indirect). The Kathmandu area has a GDP slightly higher than the rest of Nepal. The direct epicentral region has a lower GDP per capita in comparison. Agriculture (outside Central) and trade are the key components of GDP.

What have been the 2 largest comparable damaging events in the past? None exactly in this region.

Date - Name	Impact Size	Damage %	Social % or Insured %	Economic Loss
1934 Bihar	Mw8.0, IX	80,000 bldgs destroyed	10,700 deaths	Ca. $25m USD
1988 Western	Mw6.8, VIII	78,000 dest./ 76,000 dam.	1004 dead, 300,000 homeless	Ca. $130m USD

Preferred Building Damage Information:

Description: *Many government, religious and private buildings destroyed.* The counting of destroyed buildings has currently been undertaken by NEOC and Nepal Police – 300,000 destroyed and 250,000 damaged. Based on displaced families, this value could be up to at least 1.5 million people. Some smaller towns around the epicentre in Gorkha District have a high % of destroyed buildings (>60%). Kathmandu – ca. 15% MDR.

Twitter photos of damage

Secondary Effect Information: For weather impacts see *http://www.wettergefahren-fruehwarnung.de/*

Type	Impact	Damage	Social	Economic %
Landslides	Many roads blocked, infrastructure damage	Major	At least 500 deaths	<2%
Avalanches	Camps destroyed, many deaths	Minor	At least 20 deaths	minor

Preferred Social Impact Information:

Type	Median	Accepted Range	Description	Source
Deaths	**8254 (25.04)+ hundreds (12.05.)**	Ca. 350 missing	1400-7500* = initial estimate 7560 (3570-11970)* = updated intensities 9100 (5700-14000) = 2nd update	Daniell, CATDAT, EQ Report.
	***NB: 8151 Nepal, 25 China , 75 India and 4 Bangladesh as of 16.15UTC 11.05*			
Injuries	**17861**	May rise	Still counting	News
Homeless/Displaced	1300000	1200000-1700000	Estimated 8 million affected, and 1.3 million homeless due to destroyed buildings	

*predicted

Preferred Current Economic Impact Information: $million int. event-day dollars

Type	Median	Accepted Range	Description	Source
Replacement Cost (inc. triggered quake)	**$5930m**	$4880m-$8440m	Replacement Cost (without indirect/life) - $2.5-3.2bn USD in building costs	CATDAT
Total Loss	**$3860m**	$3210m-$6020m	Total estimate (using rapid loss model)	CATDAT/ Daniell
Insured Loss	**<$100m**	unknown	Could be some business interruption	CATDAT
Aid Impact	**Ca. $200m**	+++ relief workers	International community	EQ Report

Direct Economic Damage (Total) - Summary

- The rapid loss estimation of CATDAT/James Daniell, gives a total damage value coming out to between 3-3.5 billion USD with a replacement cost (>5 billion USD) totalling over 25% of GDP, remaining like the first report.
- The 2nd triggered earthquake has caused much additional damage.
- Indirect losses and total macroeconomic effects in the order of $10bn USD (50% of Nepalese GDP)

Social Sensors & Disaster Response

- The alerts came out from twitter TENAS, within a couple of minutes after the event, with EQ Report alerts coming a minute later after Indian felt reports.
- Twitter and Facebook have been monitored since for use in these analyses.
- Information gap analysis and disaster response has been followed in this event.

Insured Loss Estimates:

Much public and critical infrastructure damage occurred, and in addition there was damage to cultural and tourist facilities in various locations. It is still expected that the damage will be insignificant for the insurance industry. There could be global supply chain issues with export/imports however major impacts are unlikely.

Abridged Summary Description from full CATDAT description sources: see first report.

CATDAT Economic Index Rank:	8: Very Damaging	**CATDAT Social Index Rank:**	9: Very Destructive

This report was produced in conjunction with the CATDAT database, earthquake-report.com, GEOFON and USGS data. As shown below is full size documentation of the diagrams shown in the summary above. The data is current as of 12th May 2015, 2:00pm European Standard Time. For the current data on losses, go to www.earthquake-report.com via www.cedim.de

The following report contains:-

Institutions of authors contributing to this report:

CEDIM Center for Disaster Management and Risk Reduction Technology, a joint interdisciplinary research institute by GFZ and KIT, www.cedim.de

GFZ German Research Centre for Geosciences, www.gfz-potsdam.de

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SOS SOS Earthquakes, www.earthquake-report.com

CATDAT Global Natural Disaster Loss and Exposure Databases, www.catdat.de

EMI Earthquake and Megacities Initiative, www.emi-megacities.org

1 Information on the Triggered Earthquake of 12.05.2015

The hypocenter of the Mw 7.3 earthquake on May 12th, 2015 at 7:05 UTC (12:50 local time) was located around 80 kilometers northeast of Kathmandu, Nepal at 10 kilometer depth (GEOFON). The rupture plane strikes parallel to the Himalayan Belt WNW to ESE, dips with 10° to the North and extends about 60 km along strike and 20 km perpendicular to it. The maximum PGA was estimated at 0.4g.

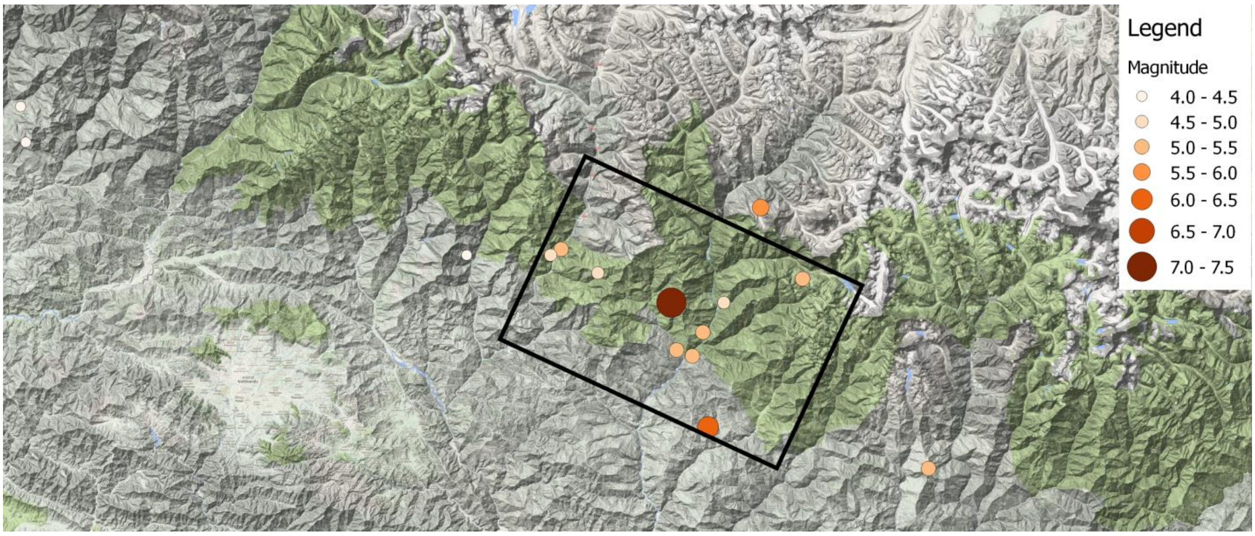


Figure 1: Aftershock sequence of the M7.3 earthquake of May 12th, 2015. 4 Magnitude 4 earthquakes are also shown, which occurred within 24h before the mainshock.

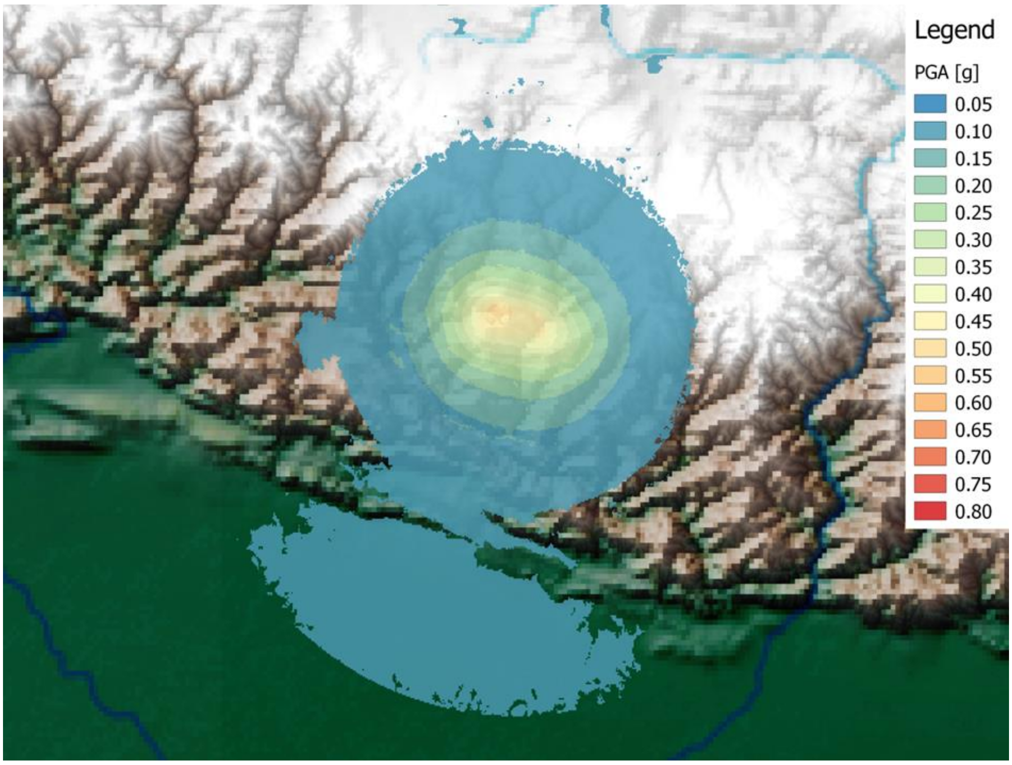


Figure 2: PGA Map (ground motion, g) of the M7.3 earthquake of May 12th, 2015.

The following is the likely death toll for the May 12th triggered earthquake when using 40% occupancy and the CATDAT model for fatalities.

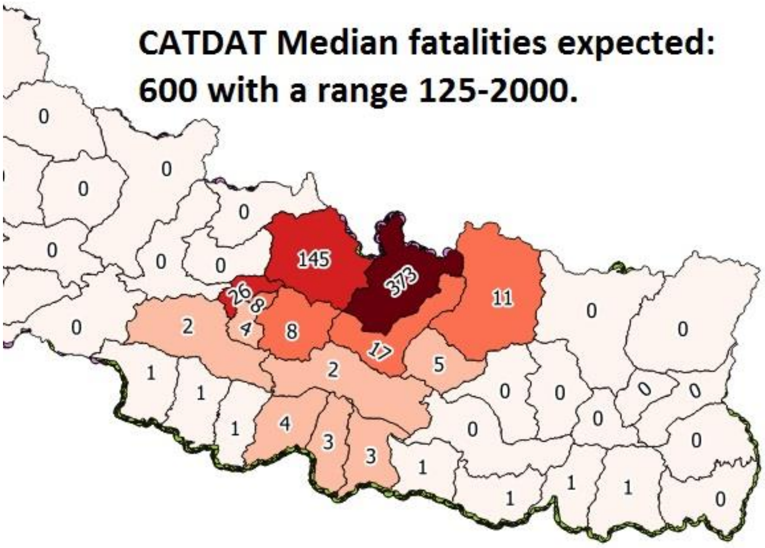


Figure 3: Updated CATDAT fatality estimate using 40% total occupancy: median 580 fatalities with a range from 125-2000. If the population is lower due to the mainshock, then this will be reduced.

The economic losses for this event are estimated at $250-1200 million with $550 million coming from additional damage. This excludes the previous losses from the M7.8 earthquake and does not include the potential extra landslide deaths and losses.

2 Fatalities and other Social Impacts from the 25.04.2015 Earthquake

Current Fatalities

As of 29th April 2015, the Nepalese government has released results in English in real-time, thus the need for translating Nepali transcripts of fatalities and creating maps was stopped by CEDIM on the 29th April 2015. For maps of fatalities refer to drrportal.gov.np.

The death toll as of the 12th of May 2015 was 8151 with another 377 missing. In addition, there have been around 100 fatalities in Tibet, India and Bangladesh.

This is the 38th highest death toll earthquake since 1900 (ca. 8500 deaths). Thus, an earthquake of this death toll has occurred on average every 3 years. Thirty-six earthquakes with over 10,000 deaths have been recorded since 1900.

Additional fatalities have occurred due to the M7.4 aftershock of the 12th May 2015 event with a number in the hundreds expected in addition to those from the original event.

Modelling fatalities in near real-time

Using the rapid socioeconomic loss model of Daniell (2014), fatalities were calculated for the Nepalese earthquake starting 25 mins after the event using socioeconomic fragility functions. These functions rely on MMI intensity, population, human development index and the time of the earthquake.

The initial estimate released on Earthquake-report.com was of 1400-7500 fatalities with an expected value of 1750. The time of day has been calibrated as part of each historical event since 1900 and makes a large difference in the final fatalities. In the initial model, the value was set at 0.34. This referred to the fatalities coming directly from shaking, and did not include landslide deaths.

Subsequent updates on the day following the earthquake, with improved intensity data, an updated population model using ward level population data from census information, as well as more detailed time of day data, put the total time of day factor at around 0.5, as well as giving a new estimate of fatalities with 7560 median deaths estimated in the first CEDIM report on the 27th April 2015 with a range given of 3570-11970.

This was subsequently updated with each improved PGA map and part of intensity information, with a value of 8000-9000 deaths (median) released as part of an article on the method in Scientific American on the 29th April 2015 (http://www.scientificamerican.com/article/experts-calculate-new-loss-predictions-for-nepal-quake/)

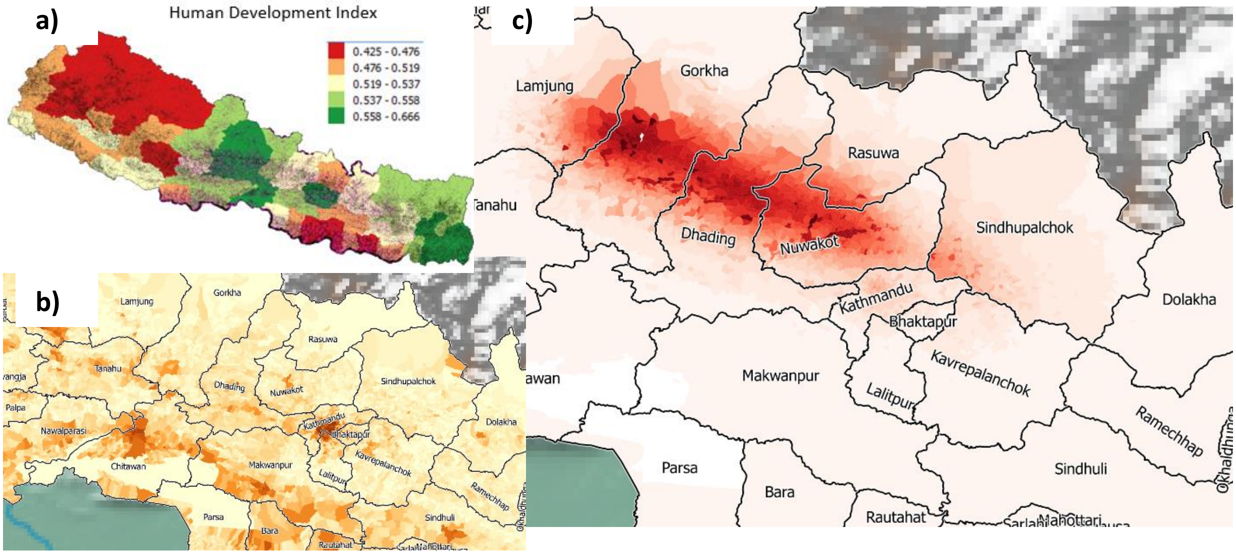


Figure 4: (a) Human Development Index as integrated into the socioeconomic fragility functions; (b) Ward level population for Nepal (as of 25.04.2015); (c) Modelled relative fatality rate (% deaths per population)

The current estimates of fatalities using the new PGA map come out to around 9100 shaking deaths with a range of 5700-14100. This takes into account a PGA value of 0.16-0.2g in Kathmandu.

Comparing this to the actual fatalities recorded so far for the 10 districts with the greatest number of fatalities, the model overestimated the fatalities slightly in the west, and underestimated in the east. However, the total fatalities are very similar.

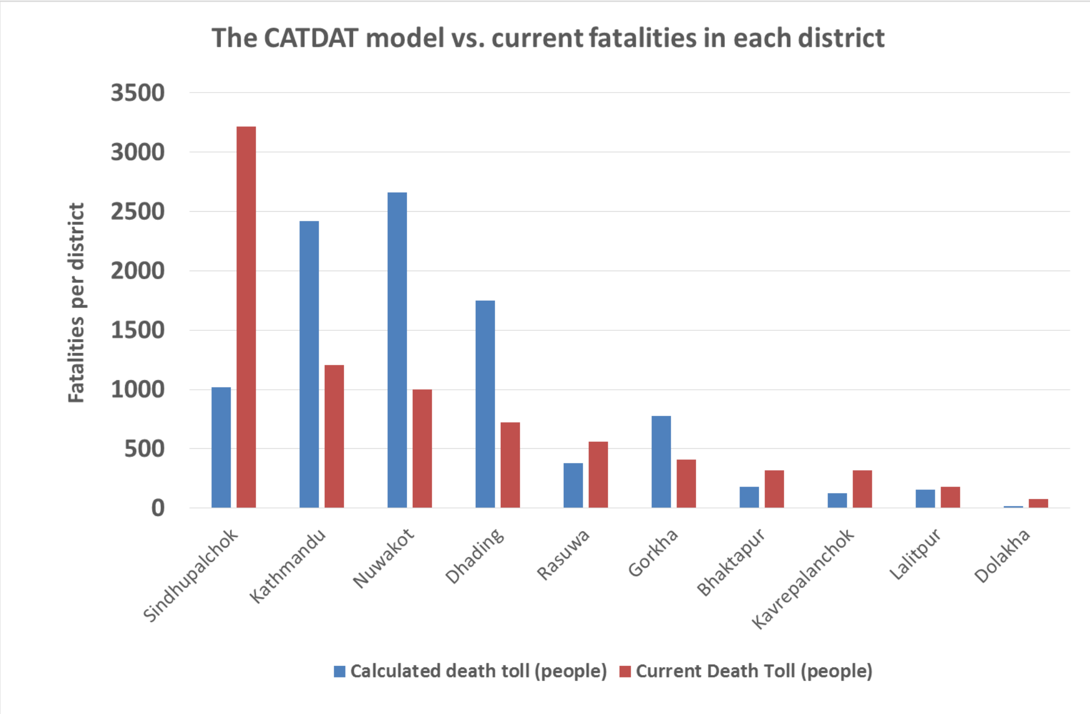


Figure 5: CATDAT modelled fatalities vs. the current fatality count in each of the worst affected districts

Deaths due to landslides have been reported throughout Nepal totaling around 650 so far, but most coverage has been centered on the deaths in the Langtang landslide where approx. 300-350 people have perished. In addition, landslides throughout Rasuwa and Sindhupalchok have caused many deaths. For landslides the best source of information is the group of *British Geological Survey, Durham University, ICIMOD, NASA, and University of Arizona* who are working on landslides in this event.

http://ewf.nerc.ac.uk/2015/05/08/nepal-earthquake-update-on-landslide-hazard-2/

Why is the fatality rate lower than some other estimates?

In the first few days after the event, there were many differences between rapid fatality models globally. The model of WAPMERR (QLARM) (Wyss, 2015), had a value of 57,700 deaths, and a total fatality range from (20000-10000). The model of USGS-PAGER from 15 hrs 36 min after the event (Jaiswal and Wald, 2009) had a 52% chance of fatalities being greater than 10,000. With the refined USGS Shakemap (as of 7th May 2015) following station data in Kathmandu, the fatality estimate reduced to under 10,000 as a median but with the ranges indicated as in Figure 6.

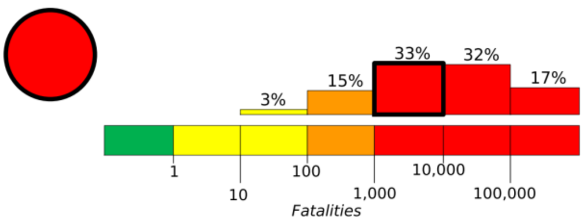


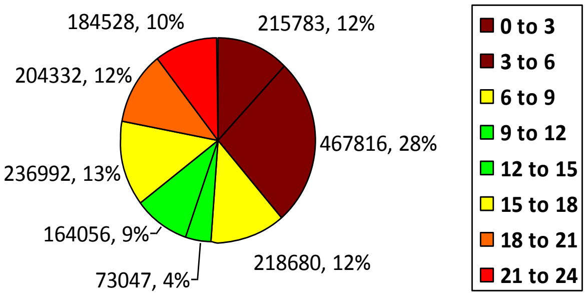
Figure 6: USGS-PAGER estimate (12th May 2015).

There are 4 key factors for a reduced death toll in this case:-

1) TIME OF DAY

The earthquake occurred at 11.56am local time on a Saturday without much precipitation. It was a time when many people were outside of their houses and working in fields, or travelling around, as the earthquake occurred on a Saturday.

From the CATDAT Damaging Earthquakes database, there are some striking trends in fatalities when disaggregating by the time of the day that historical fatalities have occurred since 1900.



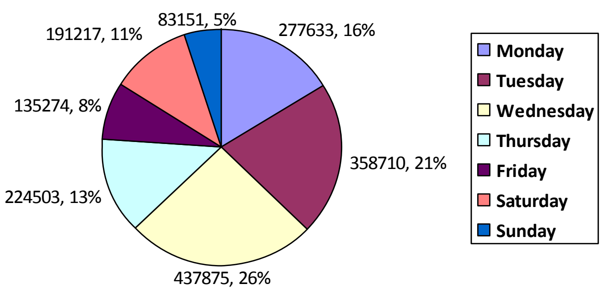


Figure 7: Left: Worldwide earthquake shaking deaths by time of the day with colours indicating occupancy during certain times; Right: Deaths per day of the week in historical earthquakes since 1900.

From these, and other author studies, in Daniell (2014), time of day functions were derived for various locations in the world (with of course much uncertainty, due to weather and other external factors.

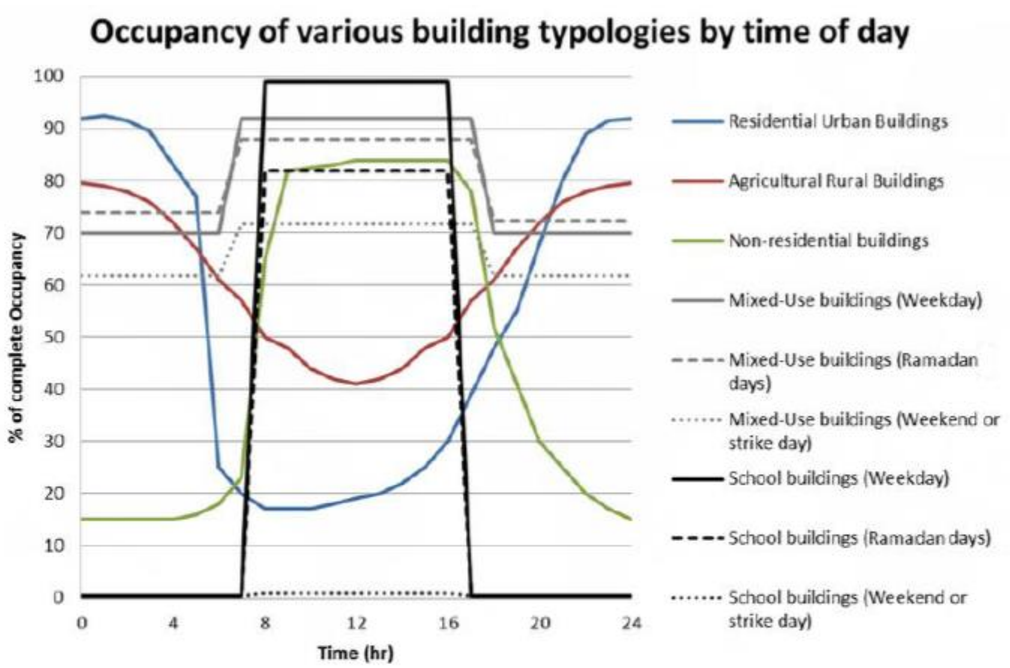


Figure 8: Occupancy of various building typologies by time of day showing the differences between typologies on weekends and during the week. These combine data from Coburn and Spence (1992) and Ara (2013) in Bangladesh.

The different typologies have very different occupancies depending on when the earthquake occurs.

2) BUILDING TYPOLOGY

Although almost 300,000 houses were destroyed, the death toll appears to have been reduced in part due to the fact these were rural masonry buildings with tile, sheet or non-heavy roof structures.

In similar events globally of this magnitude or shaking (high M7, ca. 0.2-0.6g) with these types of collapse rates, Sichuan 2008 is a good example where 65,000 people died as a result of building damage. Most of these buildings were also built of unreinforced masonry (although in a slightly different style) and caused similar fatality rates. In 1.7 million destroyed houses (ca. 5 million rooms), 65,000 died. As a ratio this is 1 death per ca. 250 destroyed houses. In the current event, the ratio is in the order of 1 death per 350-400 destroyed houses (however, it is important to take the time of day difference into account). Thus both earthquakes have similar ratios.

In Kathmandu, from photos seen from the field, it appears as though low quality building and material (i.e. concrete strength), additional rebar and other safe building practices saved many catastrophic collapses, thus reducing the death toll.

3) GROUND MOTION

In many cases in rural towns, there was enough time for people to leave their houses given the frequency content and shaking mechanism. A few reports from towns indicate that only the elderly or pregnant women unfortunately were unable to run out in time.

4) COMMUNICATION AND RAPID RESPONSE

In this earthquake, the mobile networks did not go down in Kathmandu, with data response being available. Thus, ambulances and other medical staff were able to be mobilized quickly. The sense of community in Nepal is also so that on videos of the earthquake from Nepal, in each case where structures have fallen on people, a crowd immediately rushes to pull rubble off injured people. The lack of machinery for concrete structures was a problem as well as the geographic nature of Nepal meaning that small communities could not be easily reached, however, also from these rural towns, villagers rushed to the rescue of trapped people and given the lighter nature of structures, were able to free them.

Shelter Impacts

A detailed report was undertaken on the shelter impacts of this event in CEDIM Report #2. Please refer to this report as well as the updated homeless numbers above.

http://www.cedim.de/download/CEDIM_FDA_NepalEarthquake_Report2Shelter.pdf

There will be additional effects that will be discussed in a future report including the 12.05.2015 mainshock.

3 Economic Impact of the 25.04.2015 Earthquake

The capital stock of Nepal is very low comparatively in the region, and the country has a combined building and infrastructure net capital stock as calculated using the method in Daniell and Wenzel (2014) on data up until 2015, of 38.8 billion USD. The gross capital stock of all structures, contents, equipment and materials is equal to around 59.1 billion USD. The GDP of Nepal is currently around 19.71 billion US$ as of April 25th 2015, using forward projections and current exchange rates of 101.8 Nepalese Rupees to the USD.

The modelled effects of the earthquake have been created using modified intensity data. The following estimates have been released using the empirical socioeconomic fragility functions of Daniell (2014) based on historic earthquakes globally.

Economic estimates have been released since the disaster with an estimate of $1.36-3.68 billion released in economic losses (net capital stock loss) being the first loss estimate from the CATDAT system on the day of the event. This was around the $2-5.5 billion USD mark for replacement costs.

On the first day, these values were updated to $1.9-4.2 billion USD with the improved intensities with a median value of $3 billion USD. Since then, these values have not changed significantly since the start of the reporting with a loss estimate of around $3-3.5 billion USD for the net capital stock and production losses. For replacement costs and production losses these were estimated in the order of $5-5.5 billion USD with a large proportion of these losses coming from Kathmandu, simply due to the high economic influence of the city.

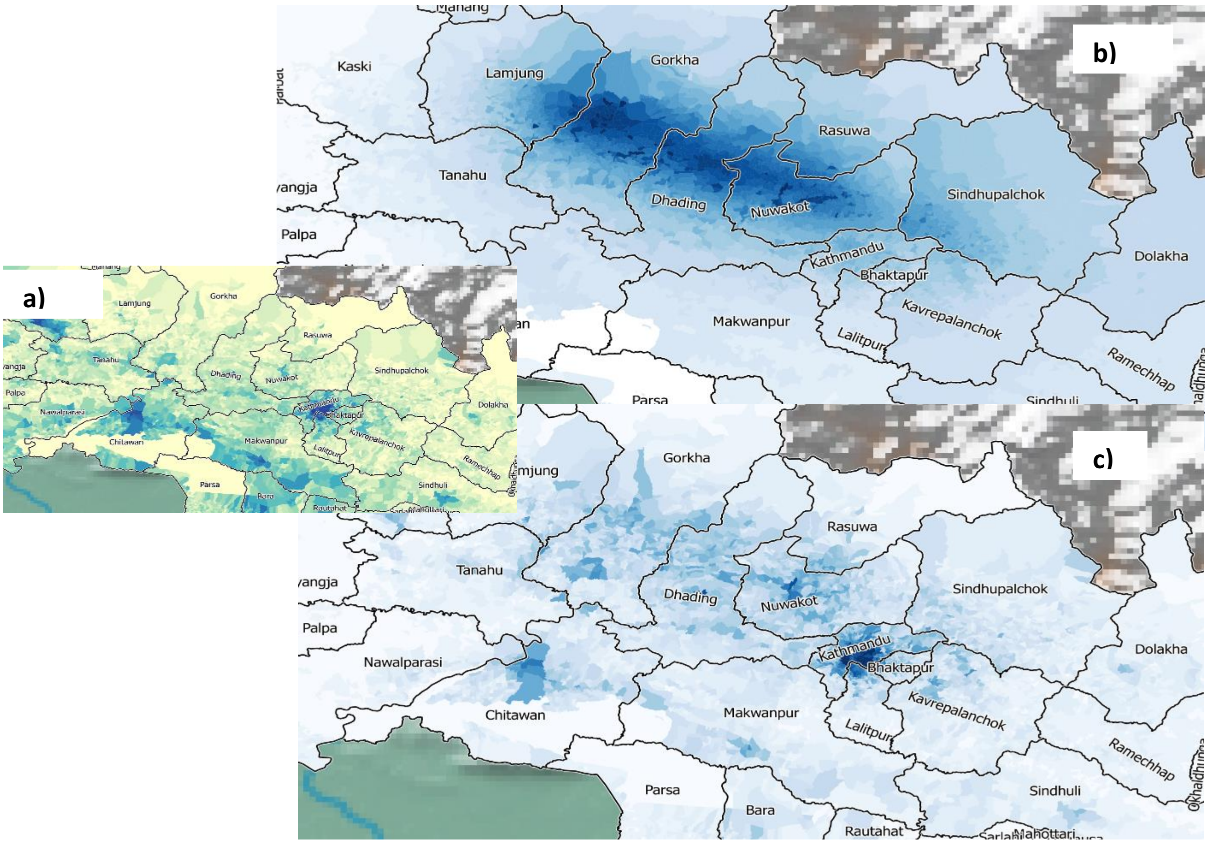


Figure 9: (a) Ward level Gross Capital Stock estimates as integrated into the socioeconomic fragility functions; (b) Modelled economic costs in relative terms (% costs per dollar value) – dark blue = high, white = low; (c) Modelled economic costs in absolute terms (dollar values) – dark blue = high, white = low.

The economic loss remains the same as the report from the 27th April 2015 at around 3.5 billion USD (2.8-4.6 billion USD) from the CATDAT model as released through Earthquake-Report and CEDIM. The replacement cost is estimated at around 5.3 billion USD (4.28-6.84 billion USD) using the intensity patterns and historically observed losses. Despite minor changes in intensities since the last report, only the distribution of losses has changed, with slightly less observed in Kathmandu and higher loss ratios in Gorkha, Rasuwa, Nuwakot, Sindhupalchok and Dhading.

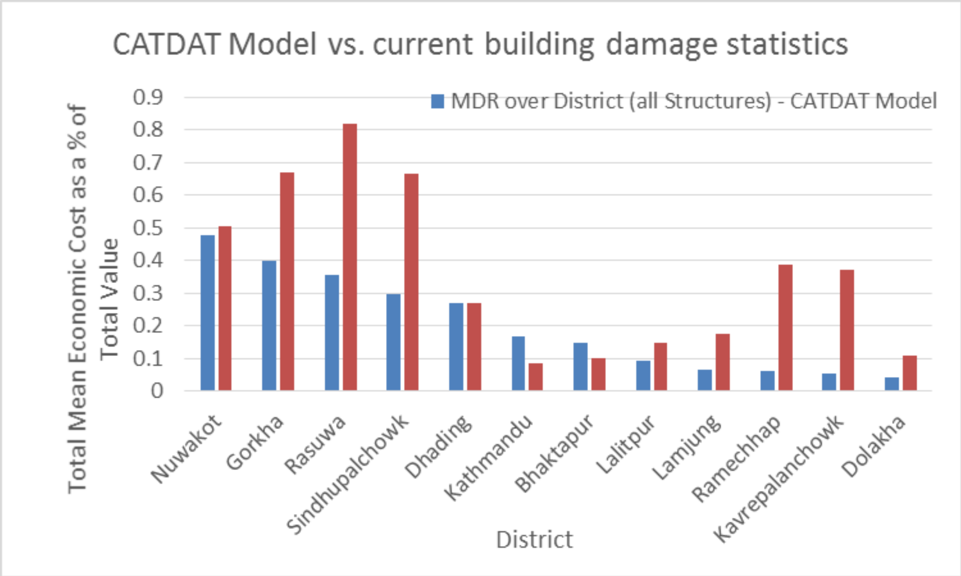


Figure 10: Modelled Economic Costs through the rapid model in CATDAT (Total economic costs to infrastructure, buildings etc.) vs. Observed Losses as reported by the government (in terms of private houses). The total MDR % for the districts will be likely lower than the observed rate in this graph, as housing is one of the more vulnerable sectors, thus not representing the total loss accurately.

The current impacts are estimated as follows:-

- Total Economic Effects in the order of $10 billion, with direct effects ca. $5 billion
- $2-2.7 billion replacement costs in building costs (modelled)
- $1-1.3bn infrastructure costs.
- $1.5-2bn production-equipment losses.
- *$2.5-3bn long-term human capital losses based on fatalities and injuries*
- *$2-4bn in indirect losses (1-yr)*

The cultural impact as a result of temples and religious relics that have been lost is unquantifiable. Once reconstruction begins, there will be a better idea of the costs and more importantly the time taken to restore these integral parts of Nepalese culture.

Detailed analytical modelling has been done in conjunction with the LAC Region group of the World Bank using ward level data as well as the methodology from WB LAC, and a report will be released in the coming days. This shows the mean damage ratio in each 1km cell, with detailed building vulnerabilities examined as part of the process.

4 Indirect/Macroeconomic Impact of the 25.04.2015 Earthquake

The assessment of indirect losses for a low income economy is rather difficult. Due to the low level of development in Nepal, some crucial information is unavailable as official authorities neither provide any statistics on input-output interrelations between different sectors nor do they publish any employment statistics that can be used for evaluating the regional economic performance. However, several alternative sources offer proxy datasets that are used for the following analysis. For the case study, we focus on the 2011 data for Nepal based on the CO_2-emissions from energy production as provided by www.worldmrio.com (Lenzen et al. 2012; 2013).

Based on an approximation of the nationwide input output data (2011), we conducted a basic key sector analysis by calculating forward and backward multipliers resulting from the Leontief or Ghosh model. The table below shows some of these results. It comprises the calculated degrees of interconnectedness on the demand and the supply side. Sectors with a value greater than 1 in those two categories are to be identified as key sectors and are highlighted in the table (bold). Besides that, the share of a sector's output that is directly consumed by private households and the government is shown. Additionally, the last column includes the relative exposure of the sectors. These numbers represent the share of a sector's contribution to the GDP (Human Development Report 2014 adjusted to 2015 values) for the 19 most affected districts (by rel. death toll: see CEDIM's Nepal Earthquake – Report #1). These potential impacts are not weighted and infrastructural cascading effects are not yet implemented.

Sector	Degree of Interconnectedness		Output Directly Consumed	Rel. Exposure by GDPpC (approx.)
	Supply side	Demand side		
Agriculture	1.17	0.83	17%	21%
Fishing	1.11	0.62	10%	9%
Mining and Quarrying	1.48	0.93	3%	64%
Food & Beverages	0.73	1.20	64%	
Textiles & Wearing Apparel	0.88	1.26	50%	
Wood and Paper	**1.44**	**1.10**	**9%**	**39%**
Petroleum, Chemical and Non-Metallic Mineral Products	**1.35**	**1.18**	**20%**	
Metal Products	**1.56**	**1.20**	**2%**	
Electrical and Machinery	**1.06**	**1.11**	**13%**	
Electricity, Gas & Water	1.17	0.90	37%	49%
Construction	0.77	0.95	3%	54%
Wholesale Trade	1.05	0.78	34%	55%
Retail Trade	0.61	0.81	87%	
Hotels & Restaurants	0.66	0.94	86%	58%
Transport	1.22	0.94	30%	67%
Post & Telecommunications	1.11	0.83	32%	
Financial Intermediation & Business Activities	1.09	0.80	37%	72%
Public Administration	0.55	0.82	62%	70%
Education, Health	0.63	0.87	84%	71% - 86%

The results show that due to the location of the event and its impacts on larger cities (Kathmandu, etc.) some main (public) services are directly affected. According to the data, 72% of the financial sector is seated in the most affected districts as well as the public administration (70%), communication providers (67%) and institutions in the field of education or health services (71 – 86%). The financial sector is especially essential to many business activities as it usually contributes between 10% (Agriculture) and 20% (Transportation) to their outputs. Regarding the key sectors that are supposed to be the bottlenecks within the economic network, the data shows that 39% are located somewhere in the area. However, the breakdown of these firms can easily be detrimental to those located outside the region as they are highly interconnected. Based on the calculated impact on GDP, we assume that in terms of gross value added the economy will lose up to 50% of its performance (-9.5bn USD). Obviously, the economic system depends on foreign investments or financial aid that could accelerate its recovery.

Additionally, the supply of food and basic commodities is (of course) of highest priority. Nepal's own food industry is mainly based upon inputs from its agricultural sector and financial intermediation. Another large proportion results from intra-sectoral transfers of goods and services. In total, 76% of the food industry's output is actually contributed by other sectors. Primary inputs, e.g. subsidies or compensations to employees, are rather small in comparison with their contribution to other sectors. Any actions taken to restore the Nepalese food industry have to consider this composition which means that first of all basic input sectors need to be supported as well as ensuring the unrestricted transport of goods within the sector.

Input	**Output**		
	Agriculture	**Fishing**	**Food & Beverages**
Agriculture	11%	0%	24%
Fishing	0%	1%	3%
Food & Beverages	3%	1%	11%
Textiles and Wearing Apparel	0%	0%	0%
Wood and Paper	1%	0%	5%
Petroleum, Chemical and Non-Metallic Mineral Products	3%	2%	3%
Transport	3%	1%	5%
Financial Intermediation and Business Activities	10%	3%	10%
…			
Total Inputs from other Sectors (no Primary Inputs)	**37%**	**14%**	**76%**

5 Information Gap Analysis of the 25.04.2015 Earthquake

It has been 2 weeks since the earthquake occurred on 25 April 2015. Since that time there has been an enormous effort to gather information. There are at least 513 organizations responding to the disaster (Standby Task Force, 2015). ReliefWeb now has over 1000 documents reporting on the disaster. Yet critical information is still missing, particularly regarding where relief is either needed or being provided and plans to access or communicate with remote areas. The following 'Information Gap Analysis' is a review of the available online information. Major sources include situation updates from Humanity Road, UNOCHA, USAID, CFE-DMHA, WFP-Logistics Cluster, WHO as well as reports from the Government of Nepal, news agencies, aid agencies, and social media. A classification scheme previously developed estimates the information needed by the public to respond to the disaster to protect themselves and others. The categories are reviewed in terms of whether or not typical questions from the public are being answered. The following discusses the results of the review under those categories which may be relevant to the current response efforts. Potential deficiencies at informing the public are identified. Particularly useful information resources are also identified where applicable.

Affected Areas	What areas are affected? → How are they affected?
The following districts have been identified as being most affected: Sindulpalchowk, Kathmandu, Nuwakot, Dhading, Rasuwa, Gorkha, Kavrepalanchowk, Bhaktapur, Lalitpur, Dolakha, Makawanpur, Ramechhap, Sindhuli, and Lamjung. It is not clear how a district is classified as most affected. For example, the Global Shelter Cluster (2015) described the same 14 districts as high priority districts; however, Solukhumba, Chitawan, Bhojpur, Tanahu, Khotang, Palpa, and Shyanja districts each have over 1,000 houses completely damaged, as opposed to Makawanpur which has only 363. Many aid organizations appear to be using this list of most affected districts as a guide to directing aid. It is important to ensure that this list is not directing aid away from those who really need it. The two questions (what areas are affected? and how?) are therefore not being completely answered, as the majority of information is focused on the list of most affected districts.	
Basic Human Needs	What are the needs? → Quantities? → Where?
Shelter is the current priority as major destruction of homes has been identified in areas like Gorkha and Sindhupalchowk (90% destroyed) and Dhading, Dolakha, Nuwakot and Rasuwa (80% destroyed) (USAID 3 May). Numerous stories are emerging of villages without any food or water, and people sleeping in the open. Social media reports are quantifying the number of people in need of food, water or shelter. The information gap is linked to the inability to confirm all the locations requiring what needs, as many remote villages are still unknown since communication is unavailable. According to the Government of Nepal's website (http://drrportal.gov.np/distribution), many districts have not received any aid.	
Fulfilling Needs	Who is doing What? → Where? → When?
The Standby Task Force has created a report documenting the 513 organizations responding as of May 6th. Almost all identify who the organization is and what work they are doing. Many however are missing where exactly they are operating and their timeline for delivering aid. Furthermore the Center for Excellence in Disaster Management and Humanitarian Assistance (CFE-DMHA) (2015) state that NGO's have reached all affected districts. Exactly what aid has been provided in what district is unknown. Which districts is also unclear as some organizations are referring to 39 affected districts while others are now referring to 57 affected districts.	

<table>
<tr><td>Transportation Disruptions</td><td>What are the disruptions? › Where? › How long?</td></tr>
<tr><td colspan="2">Airport congestion, weight limits and customs clearance issues were reported but have since been resolved.

Many road closures have been identified by numerous organizations. In general, mountainous areas are not accessible by road. In addition to numerous reports through social media like twitter and facebook, Tomnod is helping to identify locations of road blocks by crowdsourcing information. Using satellite images released by DigitalGlobe, they are having people tag damaged roads, bridges, buildings, landslides etc. (Tomnod, 2015).

A timeline for when roads will be repaired or cleared of rubble is not being reported.</td></tr>
<tr><td>Transportation Solutions</td><td>Who is doing What? › Where? › When? › Outstanding Needs</td></tr>
<tr><td colspan="2">Issues with the airport appear to be resolved. Helicopters appear to be a major solution to access remote areas. There are numerous reports of helicopter evacuations of injured or vulnerable groups or delivery of aid. The identification of where and when such transports are occurring are most often being observed after the fact. There is a lack of information which identifies what villages will be provided with transport at what time in the future. A clear understanding of the outstanding transportation needs of the affected population has also not been quantified.</td></tr>
<tr><td>Medical Disruptions</td><td>What are the disruptions? › Where?</td></tr>
<tr><td colspan="2">Hospital and medical issues are being updated with locations from various aid agencies. Many reports on twitter, facebook, and quakereport, are also identifying medical needs. With the focus on the 14 ‘most affected’ districts, it is possible that disruptions to the medical system in other districts are not all identified.</td></tr>
<tr><td>Medical Solutions</td><td>Who is doing What? › When? › Where?</td></tr>
<tr><td colspan="2">There are numerous reports of different agencies fulfilling medical and health needs, including when and where. However, health activities are focused on 14 districts. The World Health Organization (2015) has identified 14 priority districts for health assistance and reports on activities being conducted within these districts. There is a lack of information about the medical activities being conducted in other affected districts.</td></tr>
<tr><td>Post Disaster Needs Assessment</td><td>Who is doing What? › Where? › When?</td></tr>
<tr><td colspan="2">Different organizations identify that they are carrying out physical assessments, but the majority of these only identify the district, and not the specific community. Instead, social media and crowdsourced information appears to be providing the majority of information needed to assess the specific needs of each community. There is general lack of information identifying where and when PDNAs will take place.</td></tr>
</table>

Resources for Affected	Who is doing What? › Where? › When?
Numerous websites, contact lists, twitter and facebook accounts have been identified that disaster affected communities can utilize as resources. Kathmandu Living Labs (KLL) is publishing requests for assistance from individuals with the location mapped. KLL has established a method for organisations or individuals to identify what needs are required or what relief they can provide and where as well as when aid has been provided to specific locations. KLL states that their reports are also being used by the Nepal Army to coordinate their relief efforts (KLL 2015). A Nepal Quake Resource Document has been created which can be edited by anyone to update information on areas affected to identify their needs, contacts, resources provided, current status etc.: https://docs.google.com/document/d/1_wLkYkBj1gFUQzpZOvNQQo10AS0vDDOLJ9k1M1eqQ3M/edit Nepal relief information portal has been created: http://nepalrelief.net/ and a Nepal Earthquake Relief Coordination Form has also been setup: https://docs.google.com/forms/d/1RvcSsBa8MUDtaG5TEbhDRaSA-Y6Gv0HLe95o5sJvie4/viewform. A resource tracker map also has been created: http://www.resourcenepal.org/resource-tracker-map.html.	
Communication Plan	How is info being disseminated? › How can the affected communicate their needs?
A survey conducted by Internews (2014) identifies what information medium people prefer from both rural and urban areas for obtaining news and information. They found that 38% of Nepalis prefer to listen to radio for their news as opposed to only 5% using the internet. UNICEF is conducting radio programs for women and children with Radio Nepal and states that it reaches an audience of 20 million people. Numerous online tools exist for affected communities with internet access to make aid agencies aware of their needs as identified in the resources category above. Information is needed regarding how to establish 2-way communication with communities that do not have internet access. The Communications with Disaster Affected Communities is carrying out a number of activities to provide disaster response information to communities including feedback mechanisms (CDAC, www.cdacnetwork.org). The IFRC and NRCS in collaboration with Nepal Telecom have signed an agreement to provide critical disaster response updates to communities across Nepal using a location targeted SMS system (IFRC, www.ifrc.org). A radio response group is carrying out assessments and a Google Map is currently being updated with status of radio stations in Nepal (http://www.acorab.org.np/earthquake/news/94).	

6 Geophysical Information

Earthquake mechanism

The hypocenter of the Mw 7.8 earthquake on April 25, 2015 at 6:11 UTC (11:56 local time) was located around 80 kilometers northeast of Kathmandu, Nepal and at an 18 kilometer depth (GEOFON) in a densely populated region. The moment tensor solution indicates a shallow dipping fault plane towards the North (the auxiliary plane solution is less probable for tectonic reasons). The rupture plane strikes parallel to the Himalayan Belt WNW to ESE, dips with 10° to the North and extends about 150 km along the strike and 50 km perpendicular to it (see INSAR slip model). The rupture process lasted for around 80 sec. The largest displacement occurred about 100 km to the East of the epicentre close to Kathmandu and is responsible for high ground shaking in the Kathmandu Valley. The rupture probably occurred on the Main Frontal Thrust (MFT). The aftershocks are concentrated in the region of the epicentre as well as 150 kilometres to the east (at the end of the rupture). See: (GEOFON Nepal event).

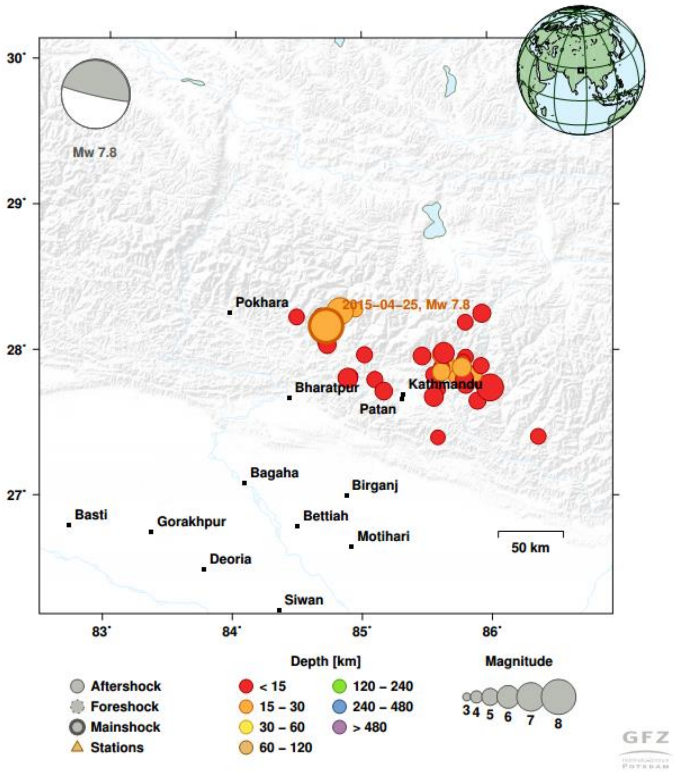


Figure 11: Nepal earthquake 25.4.2015. Moment tensor solution plotted as beach ball (upper left), main shock and aftershocks.

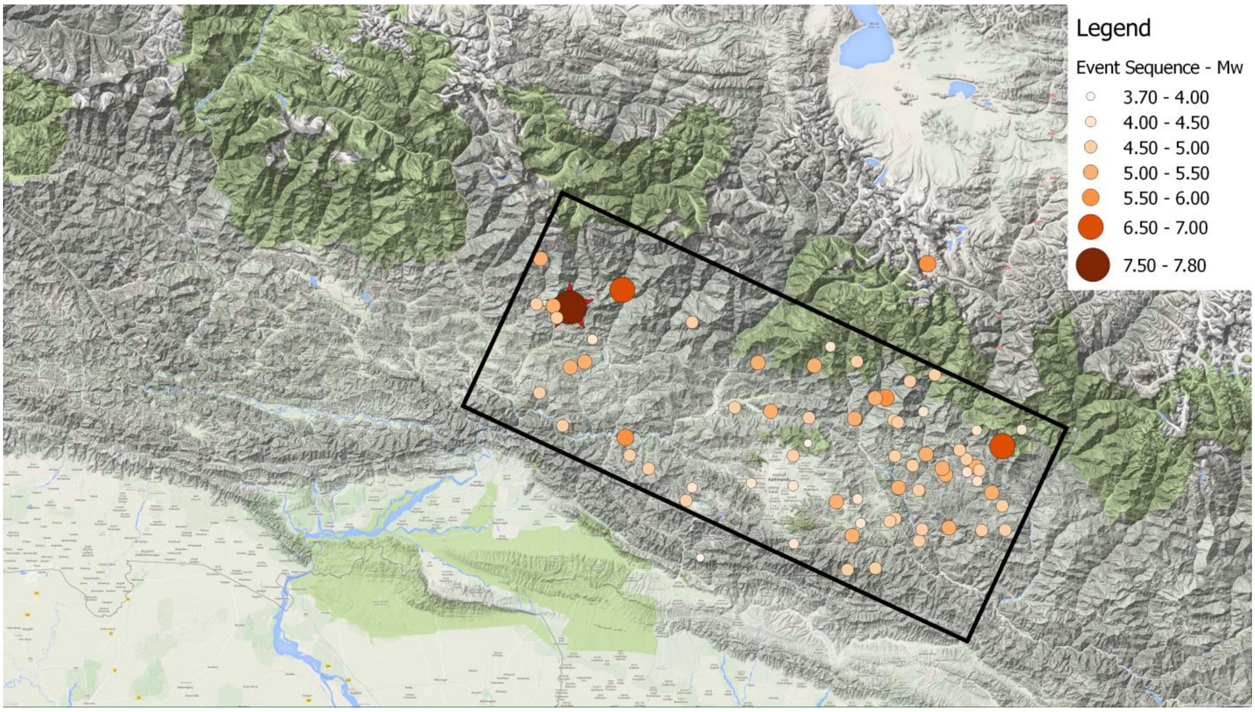


Figure 12: Nepal earthquake sequence showing moment magnitudes, including all observed events by the NCEDC seismic network until May 8th, 2015.

Tectonic setting

The east-west trending plate boundary between India and Eurasia comprises several major and minor faults distributed on a roughly 200 km wide strip between the Himalayan front and the main central thrust to the north. The seismic activity is caused by the convergence of the Indian tectonic plate to the north towards the Eurasian plate with a relative rate of approximately 40 mm per year. The shortening is accommodated by several parallel faults; hence we speak of a diffuse plate boundary. The plate boundary at the foot of the Himalaya is one of the most active continental boundaries worldwide and host of the largest earthquakes in the region.

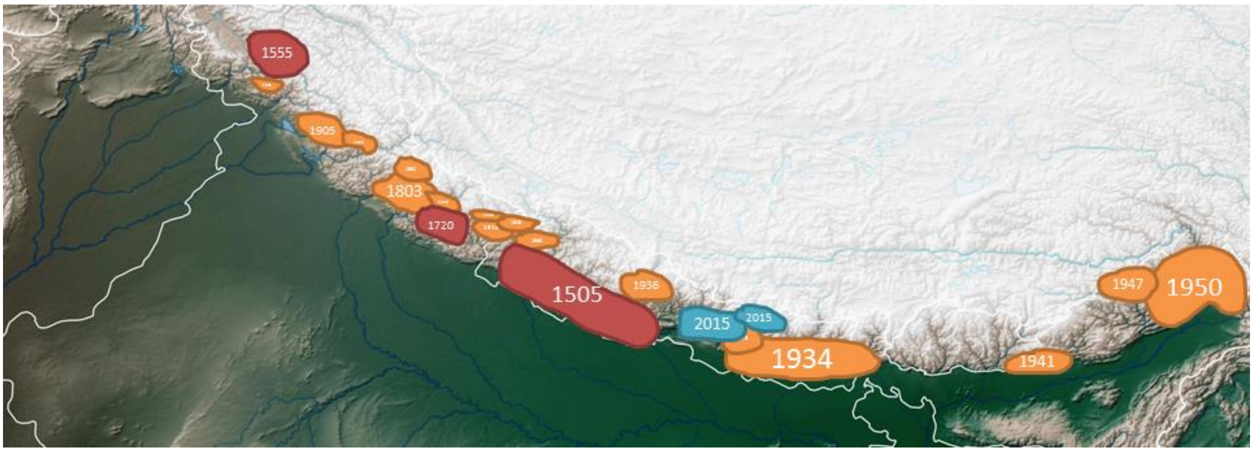


Figure 13: Historic earthquake locations along the Himalayas showing the seismic gaps as the well as the patterns of temporal seismicity.

Along this Himalayan front, several large earthquakes occurred during the last century. In the far East, along the border region of India, China and Bangladesh, the Assam earthquake killed more than 1500 people and had a magnitude of 8.6. In the direct vicinity of the 2015 earthquake, the Magnitude 8.1

Bihar earthquake had an even stronger impact on Kathmandu and Nepal in 1934 than the most recent one. In the far West, in the years 1905 and 1803, the magnitude 7.8 and 8.1 Kangra and Uttarpradesh earthquakes occurred. Regarding the last 500 years of seismicity, the location where the 1505 Lo Mustang earthquake happened is today considered to be a seismic gap, a region where a future large earthquake is expected to happen due to the on-going stress accumulation which hasn't been released during the last centuries.

The seismic pattern of large earthquakes in the Himalayans indicates local clustering. The M7.3 follow-up earthquake of May 12th shows a similar spatial pattern as the sequences of 1905 – 1906 during the Kangra event; in 1991 & 1999 during the Uttarkashi and Chamoli earthquakes; 1916 – 1926, 1926 – 1945 in Uttaranchal; and 1947 – 1950 for the Assam earthquake. About 50% of all large earthquakes during the last century can be accounted for using this pattern that strong earthquakes occur in the spatial and temporal vicinity of each other, normally within years. Thus the recent May 12th event was quite likely additionally induced by slow static triggering of the M7.8 earthquake. Additional literature: Avouac, 2003; Bollinger et al., 2006, 2014.

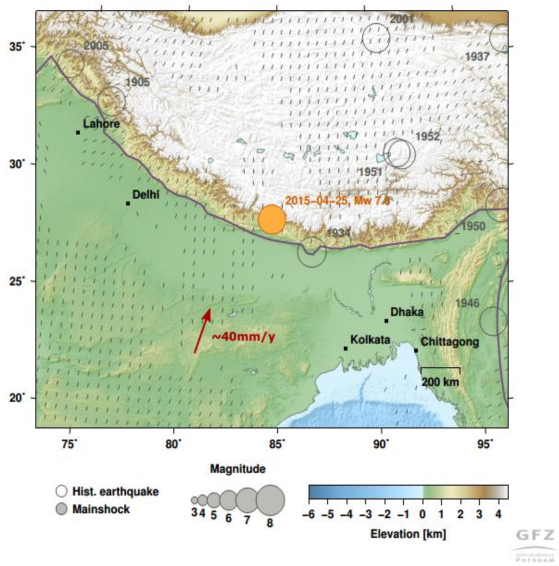


Figure 14: Red arrow: tectonic convergence. Black lines: local stress orientation (WSM, World Stress Map).

Earthquake hazard

The collision and underthrusting of the Indian beneath the Eurasian tectonic plate frequently causes strong shallow earthquakes and thus poses a significant seismic hazard. Besides the impact caused directly by ground shaking, secondary effects like landslides and liquefaction pose an additional threat.

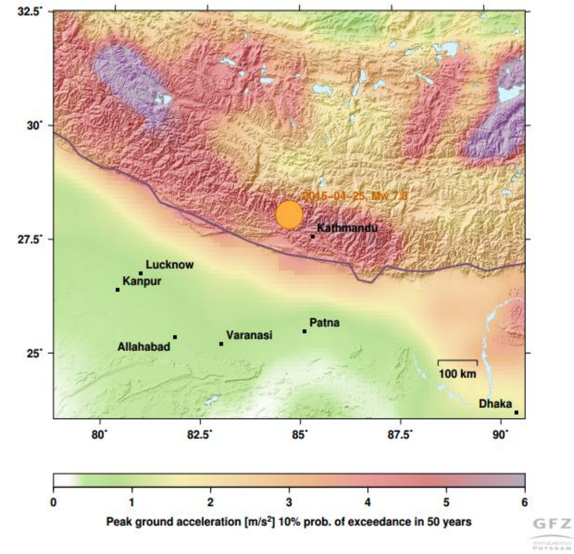


Figure 15: Peak ground acceleration probability. For the region of the present event, the global seismic hazard map (GSHAP) shows a probability of 10% for exceeding peak ground accelerations of 5 m/s2 within 50 years.

INSAR slip model

Based on InSAR (Interferometric Synthetic Aperture Radar) satellite data from Sentinel-1 by ESA, a surface deformation model caused by the earthquake was computed. This allowed the inversion of a preliminary slip model describing the spatial pattern of relative motion at the fault. Data: Copernicus (2015)/ESA/DLR Microwaves and Radar Institute/GFZ/e-GEOS/INGV–SEOM INSARAP study.

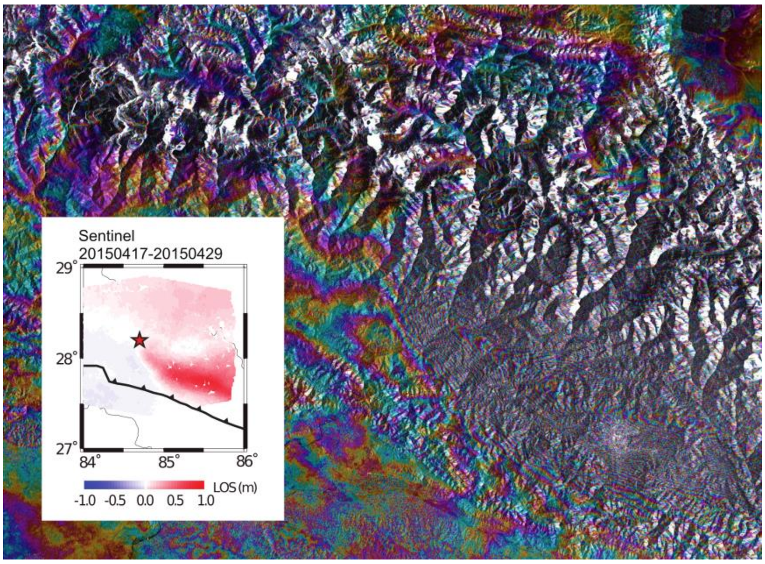


Figure 16: Interferogram: Colored fringes correspond to 2.8 cm displacement in line of sight (LOS) of the satellite. Inset: Surface deformation in LOS caused by the earthquake derived by unwrapping the interferogram.

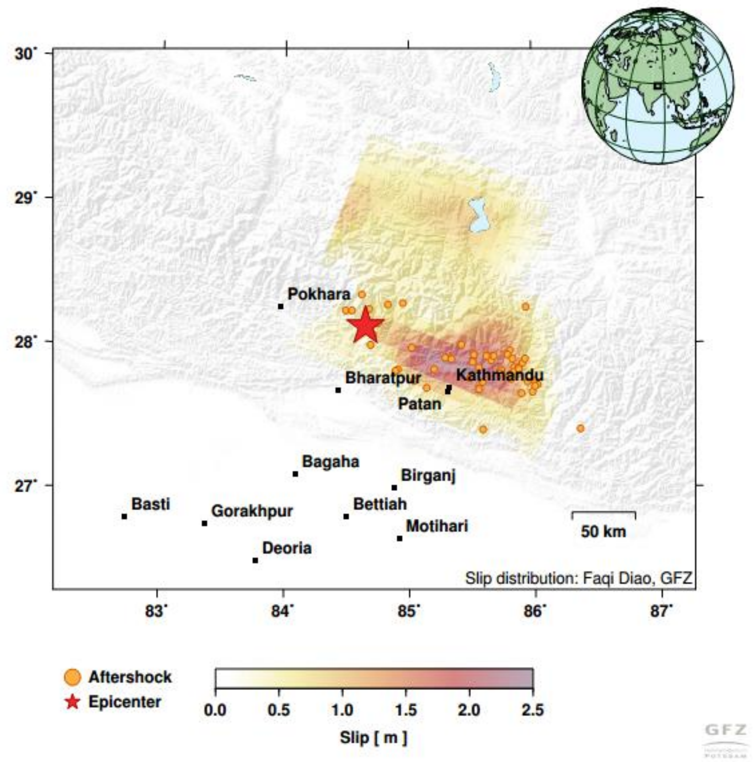


Figure 17: Inverted preliminary slip model (Faqi Diao, GFZ) based on deformation shown in previous figure. The main slip is in the area of the Kathmandu basin. (Figure: S. Heimann, GFZ).

Shake maps

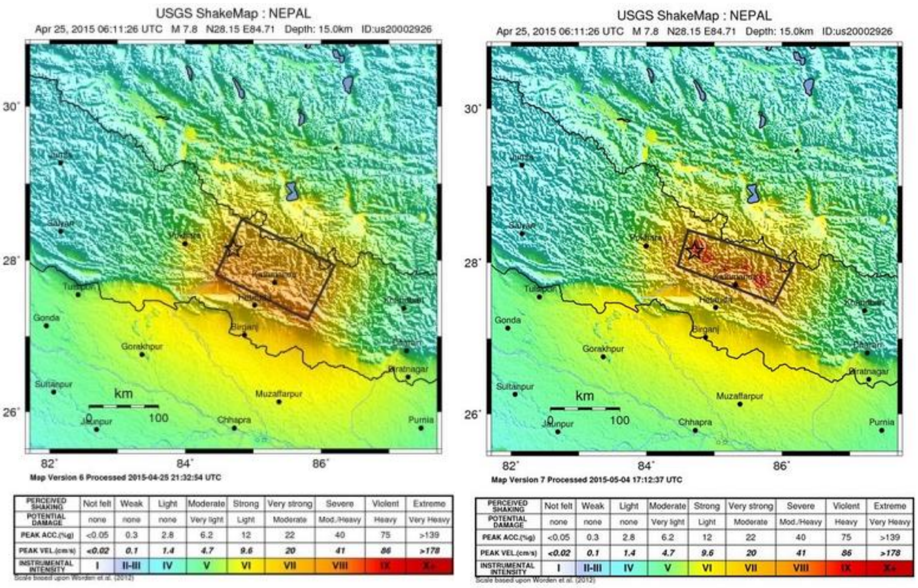


Figure 18: Shakemap Intensity Map by USGS on the Left: 27.04.2015, and Right: 10.05.2015

Higher ground motions were seen at the southerly fault plane end, with around 1g (USGS event page) and around 0.6g at Kathmandu. This has since been changed as of 10th May 2015 showing higher ground motions in the north now, instead of to the south.

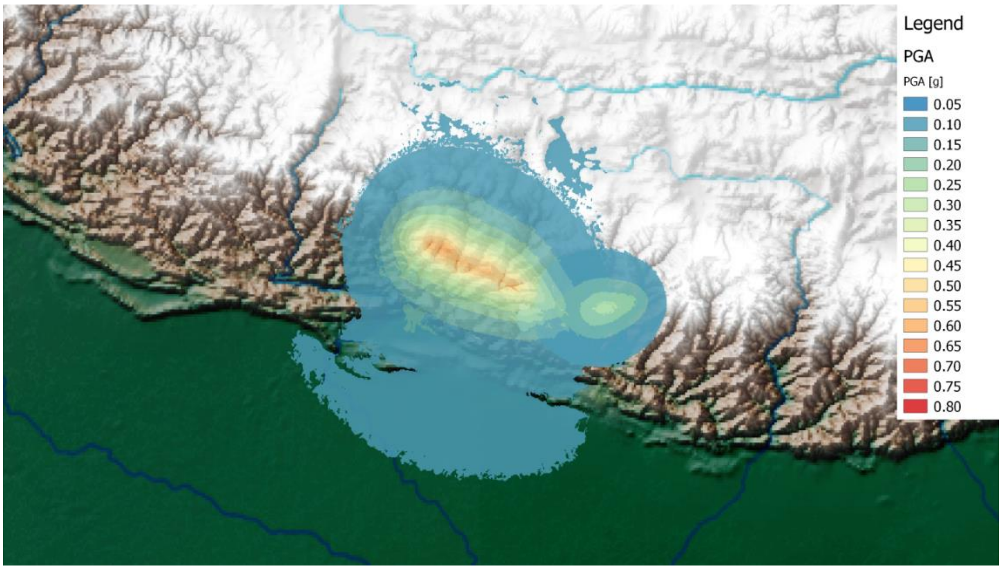
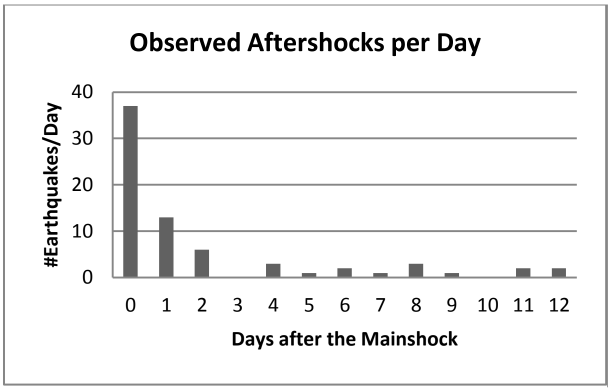


Figure 19: PGA modelling of the M7.8 earthquake on 25.04.2015 and the M6.7 aftershock

Modelled peak ground acceleration (PGA) based on stochastic rupture modelling by CEDIM is up to 0.8g in some locations, amplified by soft soil conditions in the valley along the fault rupture, however in most cases the shaking was far lower. This was the model used in our fatality and economic loss estimates along with observed data. Around Kathmandu, the peak ground acceleration was around 0.2-0.3g. However, according to modelling, 0.16g was recorded here. The M6.7 aftershock of April 26th most likely reached a PGA of about 0.2 – 0.25g in the vicinity of the epicentre. Intensity observations indicated that the mainshock epicentre was the western-most starting point of the fault rupture heading south-eastwards.

Aftershock Observations (until May 8th, 2015)

Following the aftershock modelling of the first report, aftershock activity was analysed in detail. By May 8th, 2015 more than 60 aftershocks of magnitude 4 and larger have been observed, several of them causing additional damage and fatalities within the vicinity of their respective epicentres. The largest observed aftershock of magnitude 6.7 satisfied the Bâth's law indicating the magnitude difference of about 1.0-1.2 between the mainshock and the strongest aftershock, thus a similarly strong earthquake is not expected, except for the case of future rupture propagation. A M5.5 aftershock close to the Nepalese-Chinese border was most-likely triggered by this event about 11.5 hours after the mainshock.



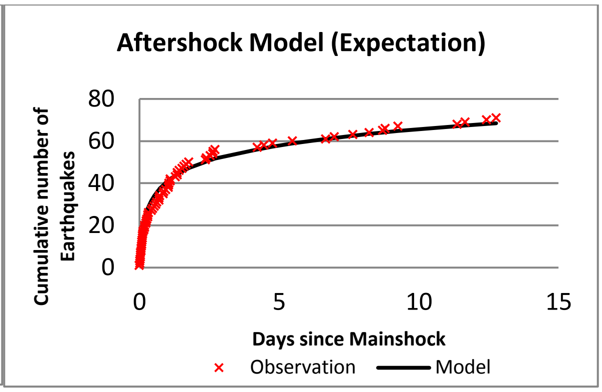


Figure 20: Left: number of aftershocks observed per day since the mainshock. Right: the cumulative number of observed aftershocks against the respective hand-fitted Omori-Utsu law

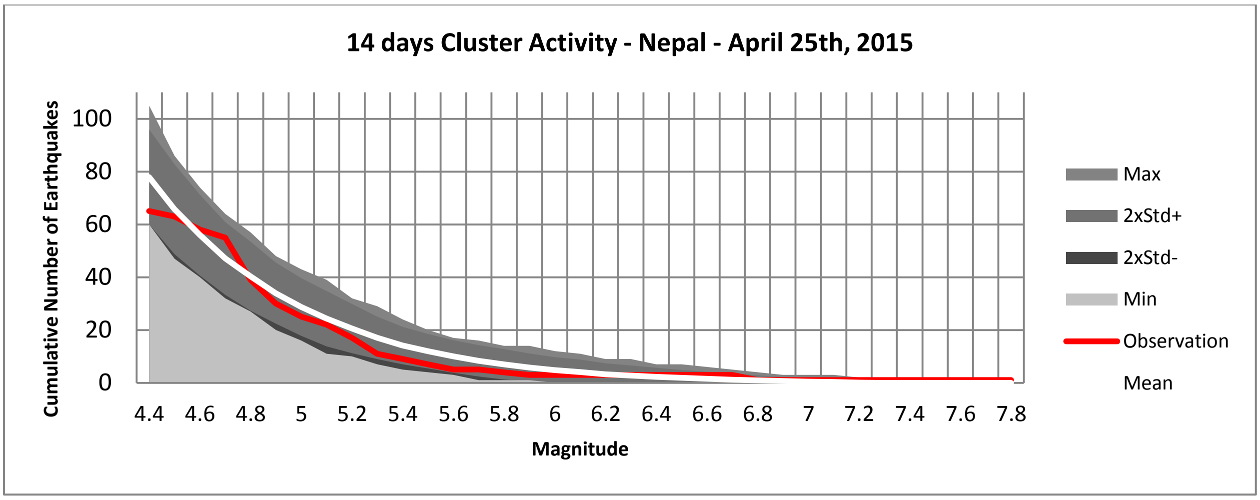


Figure 21: 14 days of aftershock modelling vs. the actual observation

The data is still considered to be incomplete for magnitudes smaller than 4.7. The model predicted a larger number of M5 earthquakes than actually observed and would have most likely underestimated the smaller magnitudes. These differences are most likely due to insufficient historic data for modelling and the characteristics of the rupture process itself. It shall be noted that almost no aftershock activity was observed to the west of the mainshock epicentre. The region appears to be locked and thus an increase in seismic activity during the next weeks and months in this area should be observed carefully!

8 Key Sources from government agencies and other organisations

Drrportal.gov.np (Disaster Statistics)

www.reliefweb.int (MapAction, CEDIM, others)

#nepalpolicehq AND #NeOCOfficial

For landslides the best source of information is the group of *British Geological Survey, Durham University, ICIMOD, NASA, and University of Arizona* who are working on landslides in this event.

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